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EMBEDDED LINUX CONFERENCE

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What's missing in embedded build systems

Arnout Vandecappelle
Mind

https://mind.be

Who is Arnout

- Embedded software architect
- Focus on Linux OS integration
- Mind consultant since 2008
- Worked for 40+ customers in multimedia, security, home automation, satellite, telecom, chips, …
- Buildroot maintainer (team of 4)

mind
embedded development

THE LINUX FOUNDATION

Overview

- Build systems
- Field Updates
- Persistence / factory reset
- Manufacturing and provisioning
- Verified boot

Build systems

- OpenEmbedded / Yocto
- Buildroot

→very configurable
→have everything for an embedded system

Build systems that cover all bases are specialised

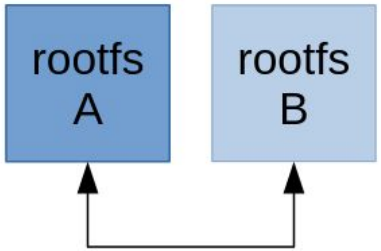
- OpenWRT
  - →explicit choices: ubus, procd, …
  - →very focused on routers
  - →missing a lot, e.g. Rust
- foundries.io Linux microplatform
  - →based on yocto, OStree, writable /
  - →tied very tightly to foundries.io cloud service

Traditional distros cover most bases

- Traditional distros take care of the desktop and server use cases
- Boot installer, update via package manager, everything writeable
- Not even ideal for desktop use case
  →https://0pointer.net/blog/fitting-everything-together.html

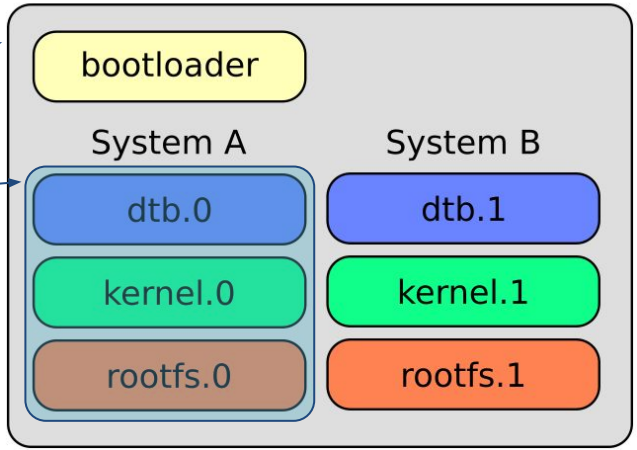
Field updates

- Every system needs field updates
- Almost always A/B update kernel+rootfs
- Tools exist:
  - swupdate
  - rauc
  - mender
  - …
- Build systems provide these tools



Field updates - what's missing in build systems

- Distinction between
  - manufacturing image
  - update image
- Default image includes partitioning for updates
- Integration of tool to produce update image



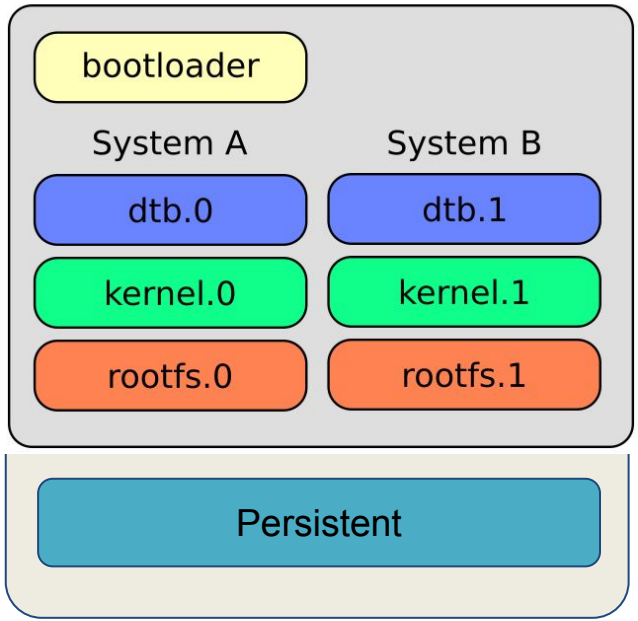
Field updates - what's missing in bootloaders

- U-Boot doesn't directly support A/B updates
  - Need to create script for it
  - Better if the logic is directly in the boot code itself (U-Boot env can be corrupted)
  - (Full) U-Boot and TF-A also need to be updateable!

- Better on UEFI
  - RAUC can directly set EFI bootorder and bootnext
  - systemd-boot can choose based on version number

Persistence

- A/B update → persistent data not in rootfs
- Additional partition/volume needed
- Must be mounted somewhere
- Must be populated



Persistent partition must be mounted

- overlayfs on /: simple, but dangerous:
  - makes / read-write → security impact
  - requires initramfs
- direct mount on /var
  - symlinks or bind mounts for /etc
- writable / + readonly /usr
  - requires initramfs

\+ must be populated (not for overlay)

  - systemd-tmpfiles
    - but doesn't *remove* files

Persistence should be standardized

- Not completely solved → improvements
- All solutions are non-trivial
  - e.g. require initramfs
- Many integration considerations
- Ties in somewhat with update system

Factory reset

- Wipe persistent partition
- Re-format and populate it next boot
  →Same mechanism as first-time populating
- Recover from corrupted persistent partition
  →fsck

Manufacturing

- Build system assumes an image that is flashed e.g. to SD card
- This is not what is done in reality
  - *Installer* on SD card or USB key
  - Bootloader loaded over USB, tftp the rest
  - ubiformat NAND flash
  - Resize partitions to match actual eMMC size
    - cfr. Yocto's wic format
- Sometimes integrated with HW test image

Provisioning

- Per-device data
- Some generated on first boot
  - ssh keys
  - machine ID
- Some come from “manufacturing database”
  - Serial number
  - MAC address
  - Password
  - Device certificates

  → These need to persist factory reset

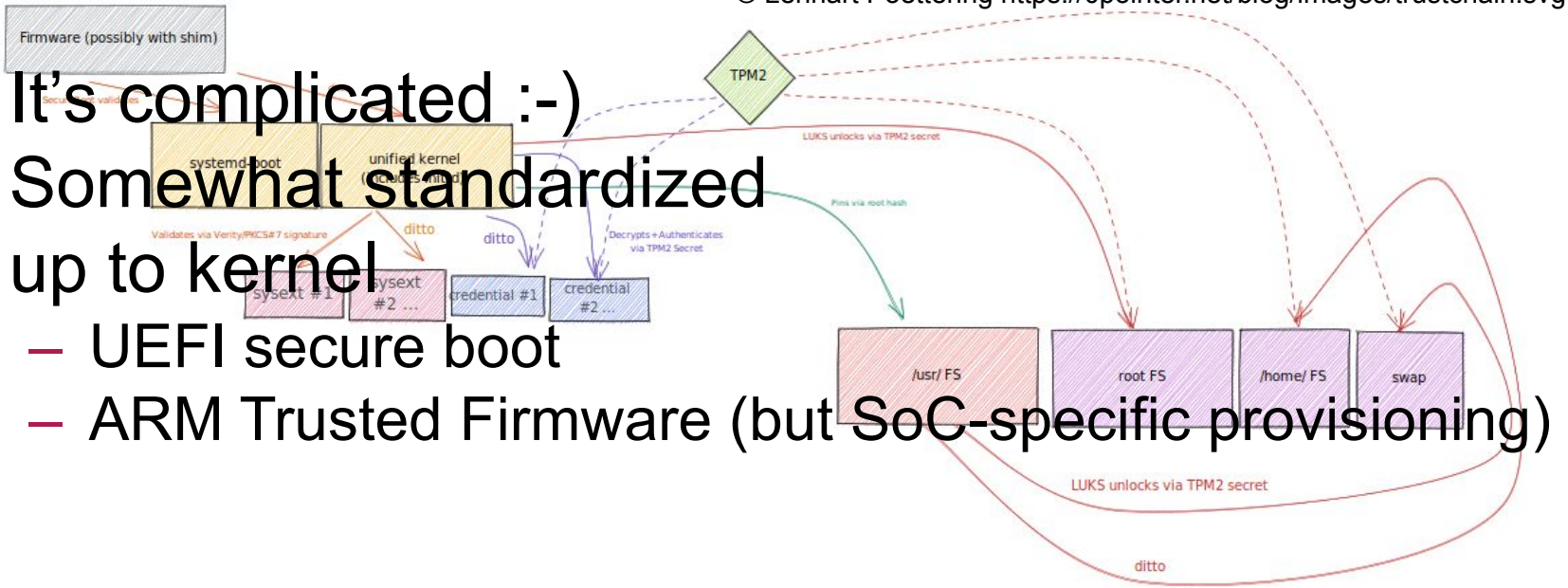
  → Separate partition needed (again)

Next steps on manufacturing and provisioning

- Currently everyone reinvents the wheel
- Define common tooling for manufacturing
  - similar to update tools
  - some amount of configurability, but not too much
- Define common partition layout for provisioning
- Integrate in build systems

Verified boot

- It's complicated :-)
- Somewhat standardized up to kernel
  - UEFI secure boot
  - ARM Trusted Firmware (but SoC-specific provisioning)



Verified boot - rootfs

- No real standard / typical verification of rootfs
- dm-verity
  - Requires initramfs to mount it
  - Requires extra partition + support at build time
  - Doesn’t (easily) work on UBI (needs block device)
- Sometimes encryption used as poor verification
  - Still doesn’t work on UBI (dm-crypt needs block device)
  - fscrypt does work on writable FS (incl. UBIFS)
    but not usable for rootfs (unless it uses shared secret)
- Remote attestation usually more important

Next steps on verified boot

- Many things still need to be improved
- Define common tooling
  - produce signed images
  - changes to bootloader + kernel to maintain trust chain
  - this is a place to discuss improvements
- Integrate in build systems
  - including impact on partitioning

Conclusions

- Developers still have to reinvent the wheel and make ad hoc choices during integration
- Build systems should make those choices
  - perhaps offer a few alternatives
  - part of openembedded-core, not just some layer
- Also additional tooling needed upstream from build systems

CONTACT DETAILS

Mind (division of Essensium)
Arenberg Science Park
Gaston Geenslaan 9
3001 Leuven
Belgium

Arnout Vandecappelle
arnout@mind.be
@arnout on GitLab
https://mind.be